DOCTOR
OF
PHILOSOPHY

MULTIMODE SIMULATIONS OF FREE ELECTRON LASERS
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The results of theoretical research on Free Electron Lasers (FELs) are presented. Basic FEL physics is reviewed, using a previously developed classical theory. Numerical simulations based on this theory are described, and numerous examples show how they have been used to increase understanding of existing FELs and to help plan new experiments. Single-mode simulations that follow the evolution of a single-frequency plane wave provide insight into important physical effects in FELs. Results show how these simulations are used to evaluate new FEL designs such as inverse-tapered and step-tapered undulators. Longitudinal multimode simulations model plane waves using finite-length electron and optical pulses. These simulations are used to study coherence evolution in various FEL designs, and to explain effects such as limit-cycle behavior. Transverse multimode simulations that allow for the finite transverse dimensions of the optical wavefronts include the effects of optical mode distortion. These simulations are currently being used to design short Rayleigh length optical cavities that are less sensitive to mirror damage. Four-dimensional simulations are also described, which follow the optical wavefront in *x*, *y*, *z*, and *t*, including the effects of multiple longitudinal and transverse modes. These simulations are computationally intensive, but may play an important role in the design of future high-power FELs.

KEYWORDS: Free Electron Lasers, Numerical Simulations, Directed Energy

A LAYERED SOFTWARE ARCHITECTURE FOR HARD REAL TIME (HRT) EMBEDDED SYSTEMS
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The current state of the art techniques to describe and implement a hard real time embedded software architecture for missile systems range from inadequate to totally non-existent. Most of the existing software implementations within such systems consist of hand-coded functionality, optimized for speed, with little or no thought to long term maintainability, and extensibility. Utilizing current state of the art software development technology, the first ever software architecture for hard real time missile software has been designed and successfully demonstrated. This component based layered abstraction pattern approach to software architecture revolutionizes reduced development time, cost, provides an order of magnitude decrease in error, and is the first such software architecture to function within the hard time constraints of the most extreme cases related to missile systems. Additionally, componentization of functionality allows for porting of software developed for one missile to any other missile with no modification. Hardware obsolescence is overcome by software abstraction layers which isolate the hardware instance from the software functionality providing a rapid, low cost transition of software from one instance of missile

hardware to another. The end result of this research is a software architecture demonstrating the capability of managing complex functionality in an accurate, quantifiable, and cost effective manner.

KEYWORDS: Embedded Software Architecture Hard Real Time

SOFTWARE TECHNOLOGY TRANSITION ENTROPY BASED ENGINEERING MODEL

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This research considers an engineering model and the relationships of various controlling parameters in an evolutionary process. Cast in terms of new technology transfer models for analysis, the model is able predict and prescribe action for a research or program manager. The model developed addresses macro level trends of a technology at the community level. The model, is based on non-linear control theory. It established the relationships of an information "temperature" with other variables, entropy, pressure, volume (nodes) and the conserved property – information in terms of messages. The research includes a comprehensive review of the state-of-the-art in software technology transfer. The summary focuses on the elements of technology transfer required to model the technology transfer process. This research specifically develops the fundamentals for a rigorous software technology transfer model. This ties together for the first time information theory, control of dynamic systems, statistical mechanics and software engineering.

KEYWORDS: Software Engineering, Technology Transfer, Information Theory, Communication Theory, Statistical Mechanics, Dynamical Systems, Control Theory, Learning Curves, Entropy, Information Temperature, Temperature of Software (^{o} Saboe), Technology Transfer Dynamics, Research Management, Diffusion of Innovation, Project Management, Physics of Software